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# SOME POINTS IN THE ECOLOGY OF RECENT CRINOIDS

AUSTIN HOBART CLARK

Although a considerable amount of work has been done on the anatomy of various species of recent crinoids, the embryology and development of two species, closely allied, are well understood, and the systematic side of the question has received more or less attention, little has been accomplished in the elucidation of the interrelation of the crinoids and the other classes of marine invertebrates, or the relation of the crinoids to marine conditions in general. This is undoubtedly due to the rarity of the group, and its chiefly inaccessible habitat, rendering it, as a whole, a difficult subject for extensive research; but much may be learned from the data already recorded, and it is the purpose of the present paper to suggest certain lines along which much of interest may be done on the basis of the present numerous, though scattered, records.

It has long been known in regard to *Antedon bifida* of the coasts of Europe that specimens taken in deep water are larger than those taken in shallow water or along the shore, though no plausible reason has been shown for the phenomenon. It has been suggested that the coldness of the deeper water may stimulate it to greater development; but specimens from different localities, taken at a considerable difference in depth, yet with the same bottom temperature, will vary greatly, those from the greater depth being much the larger; similarly, specimens from the same depth, but with marked difference in the bottom temperature, will be found to be of practically the same size. As, however, specimens from very shallow water are usually about 120 mm. in expanse, while those from deep water are 220 mm. or more, it is evident that some important factor is involved.

The food of crinoids consists of very small pelagic organisms and minute crustacea. At or near the surface the crinoid must depend upon those which swim within reach of its pinnules or which it may intercept by the slow movement of its arms; but in deeper water while this source of supply is just as available as at the surface, the crinoid gets, in addition, all the carcasses of those organisms in the levels above it which die and are precipitated to the bottom. The intensity of this rain of food increases proportionately with the depth, so that the deeper a crinoid lives, the greater is the available food supply; consequently, the better nourished will be the individual and the greater its size.

We see, therefore, that the size of *Antedon bifida* appears to be merely a question of food supply. Passing from a single species to a consideration of the group in general, we find that the average size gradually increases from the shore line to about the 100 fathom mark; this is plainly due to the gradual increase in the supply of food, as just explained; from 100 fathoms to about 600 fathoms the same size is maintained; but below 100 fathoms plant life, and with it the host of small organisms dependent directly or indirectly upon it, upon which (as well as upon certain of the minute plants) crinoids are dependent for food, begins to disappear. This gradual disappearance of vegetable organisms and their dependents is offset by the gradual increase in the rain of carcasses from above, so that an equilibrium is maintained down to about 600 fathoms, and hence the size of the crinoids remains about the same from the 100 to the 600 fathom mark. Below 600 fathoms, the gradual decomposition of the rain of carcasses progressively lessens its food value, and, therefore, we note a decrease in the size of the crinoids, hardly noticeable at first, but soon becoming more marked, until, below 2,000 fathoms, we find only the minute comatulid Bathymetra and the equally minute stalked Bathycrinus.

By this hypothesis the general absence of the Pentacrinitidæ above 100 fathoms is at once explained; the stalked pentacrinites (Encrinus, Endoxocrinus and Hypalocrinus) are animals of very considerable size; besides a large crown they have a bulky stem which must be nourished, and the organisms found at or near the surface are not sufficient to support them; it is not until the depth of approximately 100 fathoms is reached that the organisms occurring in the water about them, plus the cumulative effect of the rain of dead from a belt 100 fathoms in depth, acquires sufficient intensity to admit of their existence. Incidentally, their remarkable uniformity in size is explained; for the recent pentacrinites inhabit almost exclusively the 100–600 fathom belt, which has just been shown to be a belt of uniform crinoid size. A species of Endoxocrinus, *E. wyville-thomsoni,* and the peculiar Hypalocrinus both descend to over 1,000 fathoms, but both are much smaller than their relatives above the 600 fathom line.

The common arctic comatulid, *Heliometra glacialis* (= *eschrichtii*) occurs from east of the Kara Sea to westward of Greenland, thence southward to off Nova Scotia;[1] the southern part of the Sea of Okhotsk and the northern part of the Sea of Japan are inhabited by a variety, *maxima*, differing only in its great size. This species varies greatly throughout its wide range; north of Europe it is small, though rather larger around Spitzbergen; off Halifax and on the Grand Banks it reaches a comparatively large size, while off the western coast of Greenland it attains a diameter of 500 mm. or more, reaching 700 mm. in the Okhotsk and Japan Seas.

The west coast of Greenland abounds in fjords which are continually giving off fresh water ice which floats away, melting as it goes, thereby killing millions of small organisms which are unable to endure a great change in the salinity of the medium they inhabit; these fall to the bottom and furnish an abundant supply of food for the crinoids there, which consequently are enabled to attain very considerable dimensions. In the Kara and Barents Seas there is no such supply of fresh water at hand, hence the crinoids are small, but Spitzbergen, through its snow fields, and the consequent freshening of the surface water about it, allows the crinoids along its shores to reach a larger size than those of the Barents and Kara Seas, though they are not nearly so large as are those from west Greenland.

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[1] Stimpson's *Alecto eschrichtii* from Grand Manan is in reality *Hathrometra tenella.*

Over the Grand Banks the Gulf Stream brushes by, and mixes more or less with, the cold northern current; this is fatal to the delicate southern life it contains, which is killed and precipitated to the crinoids below; they, therefore, in spite of their living on the extreme southern limit of the specific range, are as large as, or larger than, specimens from Spitzbergen.

The Kuro Shiwo, or Japanese current, sends off a branch through the Korean Straits which washes the eastern shore of the Japan Sea, and in its northern part, from the Straits of Tsugaru to the Straits of La Pérouse mingles with the very cold water from the Okhotsk Sea. The mixing is very gradual and extends over a considerable territory, and over all this area the crinoids are of gigantic size, bearing witness to their enormous food supply. Now this colony of *Heliometra glacialis* var. *maxima,* a purely arctic species, replaced on the Pacific side of Japan and the Kuril Islands by widely different forms, and finding no close relatives nearer than the Kara Sea, might be supposed in the course of the years which have elapsed since the Okhotsk Sea was part of the Arctic Ocean, to have become rather widely differentiated from the parent stock, and to have gradually reached a larger adult size from some other cause than the question of food supply; fortunately, however, we are able to make some observations bearing directly upon this point. In this area, Heliometra is found where the bottom temperature is very low, about freezing or less; but dovetailed into these cold areas are others where the bottom temperature is 40° F. or above. These warmer areas are occupied by a fauna radically distinct from the arctic fauna of the cold areas, though the depth is about the same, and we find in them crinoids belonging to the purely Pacific genera Thaumatometra and Psathyrometra. It is gratifying to note that the representatives of both these genera are far larger here than anywhere else, the difference, in fact, being relatively greater than in the case of Heliometra. These three genera here live among entirely different surroundings, and in widely different temperatures; but their food supply, coming in a rain from above, is the same, and is, moreover, the only common ecological factor; therefore, there is no room for doubt that the food supply is the cause of the great increase in size.

While the recent pentacrinites as a rule live below 100 fathoms, in certain places, such as in some localities along the northern coasts of Cuba and Guadeloupe, and in Suruga Gulf and Sagami Bay, Japan, they approach much nearer the surface, and have even been taken in water of between 20 and 30 fathoms (Guadeloupe). Now Cuba and Guadeloupe are mountainous islands, while Suruga Gulf and Sagami Bay are close to that magnificent mountain Fuji-Yama, and to other high lands as well. The result is that many intermittent streams flow into the sea at these places, having their origin in the high lands; the rise in volume of their waters is so sudden that the pelagic life can not give way before it, but is killed and precipitated. The greatly increased food supply in the vicinity of one of these streams thus brings the food intensity up to such a level that the large pentacrinites may exist in such localities in much shallower water than would otherwise be possible. The water from these streams is never very great in amount, and does not penetrate deeply, but spreads out over the surface of the sea; thus a crinoid could exist very near the surface without being affected by it. Large rivers with a comparatively steady flow, on the other hand, freshen the entire sea for a large distance from their mouths, and thus render crinoid life impossible.

Within the tropics, particularly in the East Indies, very large comatulids belonging to the Tropiometridæ, the Zygometridæ, the Himerometridæ, and the Comasteridæ occur abundantly in very shallow water, often just below the low tide mark; moreover, they decrease in size with depth. This would appear to directly contradict the conclusion reached in the case of *Antedon bifida,* but in reality the problem is an entirely different one. Within the tropics the intense scorching sunlight causes rapid evaporation from the surface of the sea, especially where the water is shallow, and a consequent mortality among the more delicate organisms. The beaches and rocky shores, at low tide, warm up, to be covered again at high tide with comparatively cool water, full of organisms unable to stand a great difference in temperature, which are consequently killed and swept back into the sea, to fall just beyond the low tide mark. Periods of glaring sunshine are relieved by torrential rains, which are just as fatal to pelagic life through the sudden lowering in the density of the surface water. Thus it is evident that within the tropics the sublittoral zone and the sea bottom near the shore line offer the maximum food supply for the crinoids, and explain the occurrence in such localities of members of these four families of very large size.

But torrential rains are associated with mountainous districts; a glance at the distribution of the species of these four families shows that all of the large species and practically all of the small ones occur exclusively about mountainous islands or near high mainland, and they are particularly abundant along the shores of the larger East Indian Islands. On isolated coral reefs and about the shores of low coral islands where, owing to the very low altitude of what little land there is the rainfall is very small, these large littoral crinoids are quite absent.

The comatulids are divided into two great groups, one with triangular pinnules and small eggs, the Thalassometroida, the other with round pinnules and large eggs, the Antedonoida. The forms with small eggs, being no smaller than those with large eggs, may reasonably be supposed to require a longer period for development. This would imply a greater duration of the free swimming larval period, which would result in greater powers of dispersal, hence a greater geographic range. Moreover, a slowly developing larva might be supposed to possess a greater power of adaptation to environment, and therefore a certain ability to colonize new places under changed conditions, for instance, to spread downward to great depths.

The genus Thalassometra, genus of the Thalassometroida (with small eggs) has the widest distribution of any comatulid genus known, geographically and bathymetrically. It is found throughout the tropics, northward to the Aleutian Islands, the West Indies and Portugal, and southward to South Africa, the Crozet Islands and Australia; in depth it ranges from about 50 to 1,600 fathoms. Charitometra and Tropiometra, two other genera of the same group, are both intertropical, and the former reaches very considerable depths. The genera belonging to the Antedonoida (with large eggs) are mainly comparatively local and do not occupy large bathymetric altitudes. Though a number are littoral and one inhabits the greatest depths from which crinoids are now known, the bathymetric range of each is small, far smaller than that of the genera of Thalassometroida.

The beautiful and brilliant coloration of the crinoids has often been remarked; so striking is the common European species, *Antedon bifida*, that it has formed the subject of colored plates by Heusinger, Dujardin, Dalyell, Dujardin and Hupé, and Gosse; but the larger tropical species are much more varied and handsome (though colored figures of them have been published only by Leach, and by Kuhl and van Hasselt) and are, for the diversity of their markings and the delicacy of their hues unrivaled among the marine invertebrates. Observers have contented themselves with making short color notes, each on a very limited number of species, and no one has as yet made this phase of the subject an object of study, yet there appear to be many interesting points well worthy of record.

All colors are found in the crinoids except blue, though true black is confined to the disks of the Pentametrocrinidæ and to lines and spots on two species of Coccometra, and may therefore be omitted from a general discussion. Both blue and black, however, enter largely into combinations.

Yellow is the commonest color in the group, and is the color of all the more primitive forms, and of the young of almost all the others; it may, therefore, be taken as the fundamental basic crinoid color. The pentacrinoids of *Antedon bifida* are sometimes pink, though usually, like the pentacrinoids of the other forms in which they are known, yellow, and certain other forms are dull pinkish at all stages. We may, therefore, assume two basic colors, yellow and red, the latter an intensification of the former, found generally in the more specialized forms.

The derivatives from these two basic colors as they occur in the crinoids may be grouped as follows:

$$\text{I. Yellow}\begin{cases} +[\text{Blue}] = \begin{cases}\text{White.}\\ \text{Green.}\end{cases}\\ +[\text{Black}] = \text{Brown.}\end{cases}$$

$$\text{II. Red}\begin{cases} +[\text{Blue}] = \begin{cases}\text{Purple; maroon.}\\ \text{Violet.}\end{cases}\\ +[\text{Black}] = \text{Crimson.}\end{cases}$$

Under the first heading come:

*Yellow:* Bathycrinus, Rhizocrinus, Ptilocrinus, Phrynocrinus, Nanometra, Adelometra, Trichometra, Heliometra, Atelecrinus, and all but very large specimens of the species of Thalassometridæ.

*White:* Asterometra; markings on shallow water Thalassometridæ.

*Green:* Hathrometra, Coccometra, Leptometra, Compsometra.

*Brown:* Very large specimens of all the species of Thalassometridæ, Thaumatometra, and Thysanometra.

Under the second heading come, Zenometra, Psathyrometra, Bathymetra, Isometra, the Pentametrocrinidæ and Hypalocrinus.

No species is known which exhibits a perfect blending of these two basic types or their derivatives, though there are many mosaics in which both are found side by side, either in different individuals, or, more usually, in the form of a color pattern, made up partly from one base and partly from the other (each being clearly defined) in the same individual.

Some mosaic species, such as *Tropiometra afra* and certain of the Comasteridæ are peculiar in that some specimens belong exclusively to type I (yellow) and others exclusively to type II (violet) but none are ever mixed.

The mosaics are, the Zygometridæ, the Comasteridæ, the Thopimetridæ except Asterometra, Iridometra, Antedon, Erythrometra, Perometra, Hypalometra, Promachocrinus, and the Himerometridæ.

The data seem to show that the smaller stalked forms are invariably and unchangeably yellow, which color may be, as in the case of the parrots among birds, equivalent to a lack of color. Black is added to the basic color of comatulids at all depths, and appears to denote age. Blue is added apparently only within 200 fathoms of the surface, and increases in intensity to the surface. The mosaics are all littoral or shallow water types.

Species growing among coral or on white bottoms in shallow water are very dark in color, often nearly black or sharply black and white, while the same species on mud may be light yellow and pinkish; or a species may be purple and yellow in comparatively deep water, and violet and white in shallow water. We seem to be able to trace a close connection between color and amount of illumination, the blue factor in the coloration increasing with the light.

There appears to be no direct relation between the color of crinoids and their environment. The yellow deep water species are very conspicuous in the mud from a deep dredge haul, while the color of shallow water species, as just indicated, is commonly in great contrast to their surroundings. Crinoids can have little to fear, because their extremely calcareous organization would seem to make them very undesirable as food; on the other hand, a strongly contrasting coloration might be of advantage in attracting small organisms, as contrast spots on flowers do insects; observations in this point would not be difficult to make, and might lead to interesting results.

The other echinoderm classes appear to be in general subject to the same laws of color change as the crinoids, but the records are much more complete and satisfactory, and the specimens are not so much changed in preservation. They would, therefore, offer an interesting field for study.

These are some of the more interesting inferences to be deduced from an examination of the literature on the Crinoidea in its present state; and, in view of the great geological importance of the group, and its bearing on important geologic problems, it is to be hoped that this phase of the subject, as well as the systematic and anatomical sides will in the future receive its due attention.